From Bull. Zool. Soc. Egypt, 32 (1982)

IDENTIFICATION OF PLANT CELLS IN FOOD AND EGESTA OF INVERTEBRATE SOIL DETRITIVORES

By

SAMIR I. GHABOUR*, GERARD FERRIERE** AND
MARGUERITE A. RIZK*
*Department of Natural Resources, Institute of African Research and
Studies, Cairo University, Giza, Egypt and **Musée d'Histoire
Naturelle, Mairie de Dijon, Dijon, France.

Kassas and Biswas (1979) proposed that unless we can elaborate biological means for maintenance of soil fertility, together with other measures, we may not be able to avoid most of the negative effects resulting from the limited capacity of the environment to assimilate excessive inputs of energy and material in the form of fertiliziers. The fundamental rôle played by the invertebrate soil fauna in this respect, viz., breakdown and decomposition of litter, and hence in maintaining soil fertility by recycling of nutrients held up in litter, has often been demonstrated. The fauna will divide the plant litter into small fragments which are attacked by successive waves of a variety of heterotrophs (D'Aguilar 1971). With the development of modern techniques of eco-system modelling, it has been shown that what is known about the functions of producers and consumers is not matched by our limited knowledge on the functions of decomposers, and particularly invertebrate detritivores (Innis 1978, Cale and Waide 1980). Litter undergoes, during the intestinal transit in the guts of invertebrate detritivores, diverse mechanical and chemical actions which disintegrate its cellular composition. It is necessary therefore to determine how far do various soil detritivores digest and assimilate litter under various conditions, and to what extent is litter modified when it is egested as faeces. Methods for the microscopic examination of gut contents of earthworms for this purpose were developed by Ferrière (1976, 1977, 1979, 1980) with considerable success. The present paper is an attempt to further extend the utility of these methods of microscopic examination of plant cells in food and faeces, to a wider variety of animals, especially to invertebrate soil detritivores.

MATERIAL AND METHODS

The methods of microscopic examination developed by Ferrière (op. cit.) were used in the present study to examine litter used as food by a number of detritivores and the faeces collected from their natural habitats, in order to determine the content of these faeces of plant cells, usually of epithelial origin, which can be related to the cells appearing in the litter which these animals utilize as food. In each case, 30 pellets of faeces from each animal population, chosen at random, were examined microscopically. The clearing of the botanical material consisted of the following steps :

A. Fresh plant and litter.

1 — The sample is placed in a mixture of alcohol and glycerin (95:5) for 4-5 hr. to soften the cell walls.

2 — The sample is then crushed by a hard object (blunt end of a glass rod) to help penetration of chemicals.

3 — Javelle water of 18° strength (sodium hypochlorite) is added to the sample for decolouration.

4 — The sample is left for 4-5 hr. to complete the process.

5 — Formalin (1:9) drops are added to remove the Javelle crystals.

B. Faeces.

1 — One pellet of faeces is placed on a slide and covered by drops of the alcohol/glycerin mixture for 5 hr.

2 — The sample is crushed with a hard object as above.

3 — Javelle solution is added and the slide left 4-5 hr.

4 — Formalin drop (1:9) are added to remove the Javelle crystals.

5 — The slide is covered and examined.

The experimental animals used in this study were :

1. Isopods (woodlice)

The desert species **Hemilepistus reaumuri** (Aud.) was collected from the garden of the St. Menas Monastery at Bahig, 33 km. W. of Alexandria. Another isopod, **Porcellio laevis** (Brandt) B.L., from a private garden in Cairo, was also used. It represents a mesic habitat.

2. Sand roaches

Heterogamia syriaca Sauss. (Polyphagidae, Dictyoptera), or sand roaches, were collected from the maritime sand dunes on the Mediterranean coast at Gharbaniat, 53 km. W. of Alexandria, under shrubs of the species **Lygos raetam** (Forssk.) Heywood, and **Thymelaea hirsuta** (L.) Endl.; **Jasonia candicans** (Del.) Botsch. is also common and harbours large numbers of sand roaches (Ghabbour, Mikhail and Rizk 1977).

3. Snails

The snail **Eremina hasselquisti** was collected from north of the Wadi El-Natrun desert where **Thymelaea** is common. The snail **Eremina desertorum** forms a conspicuous element of the fauna along the coast and is replaced inland by the former species. **E. desertorum** faeces were provided from a population at Omayed, 83 km. W. of Alexandria, where both **Thymelaea** and **Anabasis articulata** (Forssk.) Moq. in DC., are common.

4. Mammalian herbivores

Although these fall outside the scope of this paper, faeces of camel and gazelle (a domestic and a wild herbivore) using the same range, were available at Sidi Abdel-Rahman, 120 km. W. of Alexandria, and at 20 km. S. of the coast. Inclusion of this material for comparison was found desirable. **Thymelaea** and **Anabasis** are both common in that locality.

In order to use the results of microscopic examination for comparison and analyssis of food habits, the occurrence of plant cell types could be calculated simply as a percentage, or by an importance value (I.V.) for each cell type, based on the formula of Beals (1960) :

$$\text{I.V.} = DF\tfrac{1}{2}$$

where D = density (no. of cell type "a"/no. of faecal pellets examined) and

$$F = \frac{\text{frequency (no. of occurrences of cell type "a"} \times 100}{\text{no. of occurrences of all cell types)}}$$

The resulting I.V. can either be logged or transformed into a relative importance value (R.I.V.), thus :

$$\text{R.I.V. of cell type "a"} = \frac{\text{I.V. of cell type "a"} \times 100}{\text{sum of I.V. of all types}}$$

The I.V. (or R.I.V.) of a certain cell type belonging to a certain food plant can be compared with the percentage consumption of that plant, if it could be known, by field observations or from laboratory experiments.

Plant nomenclature is according to Täckholm (1974).

RESULTS AND DISCUSSION

Plates I and II show microphotographs made of plant cells prepared from litter material collected from under the canopies of shrub species mentioned above. The leaf of **Thymelaea** is glabrous except on the inner area of the upper surface. The epidermal cells are hexagonal and thick-walled, while the compact hairs are long and sinewy (Plate I, A and B). **Jasonia** has two types of hairs, one "long" (Plate I, C) attached to the leaf surface, and the other "short" (Plate I, D) from the stem. **Lygos** stem easily gives off hairs (Plate I, E) attached to the outer borders of the stem grooves, when the stem fragments have remained on the ground as litter. Finally, the stem epidermis of **Anabasis** contains rounded agglomerations of crystals resembling mediaeval mace-heads (Plate I, F).

Table 1 (A, B and C) gives results of examination of faecal pellets from natural populations of invertebrate soil detritivores, and two mammalian herbivores, for comparison. All cell types in the faeces of sand roaches from the natural habitat (Plate II, E, F & G) could be identified, except one, the stellate hairs. On the other hand, four cell types in the faeces of animals from habitats at Omayed, Wadi El-Natroun, Sidi Abdel-Rahman, in addition to those from the Cairo garden, comprehensive atlas of epidermal cells of plants of these habitats is available yet.

The number of plant cells per faecal pellet may indicate the digestive capacity of the animal. This number varies from 6 in the snail and gazelle to 60 in the sand roach and camel. In the case of the gazelle and camel, it should be mentioned that the pellets to be examined were taken from the inside of the naturally-occurring faecal pellets, in sizes similar to the sizes of invertebrate pellets. The cells in gazelle faecal pellets were few and hard to recognize, a condition similar to the case of deer, as pointed out by Hansson (1970). Although the snail is usually regarded as a herbivore (grazer) it was reported by Hegazi **et al.** (1978) to be a detritivore too.

Two cell types belonging to **Thymelaea** may be present in the faeces : the epidrmal sinewy hairs and the hexagonal thick-walled cells (Plate II, E, F, and H). Hairs predominate (84%) in faeces of nymphal sand roaches, while hairs only could be detected in camel faeces, and none of the two types of **Thymelaea** cells could be detected in gazelle faeces. Stem hairs similar to those of **Lygos** and **Jasonia** could be detached in sand roaches have fewer cells in their faeces than

(A) from Gharbaniat

Animal		No. of cells and (S.E.)	Thym. epid. hairs	Thym. epid. hexagons	Lygos stem hairs	Jasonia long hairs	Jasonia short hairs	Stellate hairs	Xylem tubes
Sand roach	%	57.9	8.3	2.2	71.2	-	12.0	0.1	4.5
Heterogamia syriaca	I.V.	(10.6)	31.1	5.2	377.2	-	15.4	0.1	16.2
Sand roach	%	60.6	63.3	3.5	11.2	7.9	-	1.9	3.9
mixed dates	I.V.	(10.7)	379.2	17.4	58.2	39.2	-	5.8	17.3
Sand roach	%	19.0	84.2	2.3	6.8	-	-	1.5	5.3
nymphs, mixed dates	I.V.	(3.4)	160.0	2.8	9.8	-	-	1.1	6.6

Table 1 cont. (B) from Omayed and elsewhere

Animal		No. of cells and (S.E.)	Thym. epid hairs	Thym. epid. hexagons	Lygos hairs	Anabasis epid. cells	Elongate cells	Circular cells	Xylem tubes
Hemilepistus reaumuri Bahig,	%	13.3	-	-	-	0.8	96.8	2.5	-
Mar. 1977	I.V.	(3.0)	-	-	-	0.3	102.1	1.4	-
Snail (E.d.) (*)	%	6.5	71.3	26.2	-	-	-	-	4.4
Omayed Mar. 1977	I.V.	(2.1)	36.1	12.3		-	-	-	1.2
Snail (E.h.) (**)	%	6.9	1.9	2.9	-	-	94.8	0.4	-
W. Natrun Mar. 1977	I.V.	(1.9)	0.4	0.8	-	-	46.0	0.1	-

(C) camel and gazelle from Sidi Abdel-Rahman

Animal		No. of cells & S.E.	Thym. hairs	Lygos stem hairs	stellate hairs	elongate cells	circular cells	xylem tubes	unkn. cells
Camel	%	60.5	20.6	51.5	0.3	1.6	3.3	21.7	1.0
	I.V.	(7.7)	102.9	256.9	0.5	4.5	15.1	91.8	3.1
Gazelle	%	6.9	-	-	7.2	36.2	14.5	12.0	30.4
	I.V.	(2.0)	-	-	0.3	19.1	6.5	4.2	13.5

(*) E. d. = *Eremina deserturum*, (**) E. h. = *Eremina hasselquisti*.

the adults, but their pellets are also much smaller in size. Both species of the snail **Eremina** have **Thymelaea** cells, but **E. hasselquisti** (from Wadi El-Natroun) had a variety of unidentified cells which it shared with the isopod from Bahig, and with camels and gazelles from Sidi Abdel-Rahman. **Porcellio laevis,** from a garden in Cairo, had **Thymelaea**-like cells which certainly do not belong to this plant. This shows that it is imperative to examine the entire flora of a site as much as possible before attempting to draw up a consumption list of a detritivore.

Further work on these lines could lead to an identification, in quantitative terms, of variations of the diet of soil detritivores along a yearly cycle. It could also lead to detection of variations in digestibility of the same food in items in different stages of the life cycle of the animal, and hence to a more precise definition of its rôle in the turnover of organic matter. In other words, it will become possible to assess how effective the activity of a certain detritivore is in converting raw plant necromass (litter) to digested plant necromass (faeces). A food plant may fall under one of the following categories, which are by no means constant from season to season or from one stage of the life cycle to another :

a. high consumption and high faecal occurrence, i.e., palatable but weakly digestible.
b. high consumption and low faecal occurrence, i.e., palatable and highly digestible and assimilable.
c. low consumption and high faecal occurrence, i.e., non-palatable and weakly digestible and assimilable.
d. low consumption and low faecal occurrence, i.e., non-palatable but highly digestible and assimilable.

The application of this method to identify the category into which a certain food item falls with a certain deteritivore in a certain stage of its life cycle and in a certain season, may be possible under certain experimental procedures. Its application to field situations, however, will require that cells of litter plants serving as food for detritivores and present in the site, should be examined and classified into an atlas with keys for identification. This is in order to identify these cells easily and without ambiguity, once they are found in the guts or faeces, and relate them to the existing flora.

Finally, this method complements the method used by Wassif and Soliman (1979) to stduy the food of some rodents from the Western Desert of Egypt, from analysis of stomach contents and faecal pellets, and relying on the structure of epidermal cells of plants found in the same area of distribution.

SUMMARY

A method for identifying plant cells in egesta of invertebrate soil detritivores is described. Its application to some species from the Western Desert of Egypt (an isopod, a dictyopteran and two snails), and another mesic isopod from a Cairo garden, shows that the density and frequency of plant cell types in egesta, can serve to compare digestibility. It can be a useful basis to establish quantitatively the relationship between consumption of various types of food (especially litter), and digestibility, in these detritivores.

RESUME

Une méthode pour identifier les cellules végétales dans les fèces des détritivores invertebrés du sol est décrite. Elle est appliqué pour quelques espèces du désert méditerranéen occidentale de l'Egypte (1 cloporte, 1 dictyoptère, 2 escargots), aussi bien qu'une deuxième espèce de cloporte mésique d'un jardin du Caire. Les résultats montrent que cette méthode peut être utile pour préciser le rôle des detritivores dans le cycle de la matière organique ingérée. **La** densité et la fréquence des cellules végétales dans les fèces peuvent servir pour les études comparatives et comme une base pour établir la relation quantitative entre la consommation des variétés de litière ingérées et leurs digestibilité.

ACKNOWLEDGEMENTS

This research was carried out within the framework of SAMDENE Project, sponsored by the University of Alexandria, Grant US/EPA PR-3-54-1 and Ford Foundation 740-0478, and directed by Prof. M. Ayyad, Dept. of Botany, Fac. of Science, Univ. of Alexandria. Thanks are due to Prof. A. Bessard, Director of the Soil Fauna Research Station in Dijon for kind hospitality, to Dr. M. Bouché for kind advice, and to Mr. H. Moissonnier for technical assistance. Prof. W. Kühnelt (Vienna) kindly identified **Hemilepistus reaumuri, Heterogamia syriaca** and **Eremina hasselquisti.** Prof. K. Schmölzer (Vienna) kindly identified **Porcellio**

laevis. Prof. M. N. El-Hadidi (Cairo) kindly identified the plant structure in Plate II C.

REFERENCES

BEALS, E. W., 1960. Forest bird communities in the Apostle Islands of Wisconsin. Wilson Bull., **72** : 156-181.

CALE Jr., W. G. AND J.B. WAIDE, 1980. A simulation model of decomposition in a shortgrass prairie. Ecol. Modelling, **8** : 1-14.

D'AGUILAR, J., 1971. Introduction. In: D'AGUILAR, J.; ATHIAS HENRIOT, C.; BESSARD, A.; BOUCHE, M.-B., AND PUSSARD, M., Organismes du sol et production primaire, IV Colloquium Pedobiologiae, Dijon, 14-19/IX/1970, Ann. Zool.-Ecol. Anim., No. h.-s., I.N.R.A. : 13-25.

FERRIERE, G., 1976. Contribution à l'étude des fonctions des lombriciens. Mise au point d'une méthode pour l'analyse qualitative de la matière organique végétale ingérée. Mémoire-thèse, E.N.I.T.A., Quétigny-sur-les-Dijon.

FERRIERE, G., 1977. Contribution à la caractérisation de l'endentère des lombriciens : Elaboration d'une méthode d'identification des fragments végétaux ingérés. D.E.A. d'Ecologie, Univ. Cl. Bernard, Lyon.

FERRIERE, G., 1979. Etude micromorphologique des végétaux de la Prairie de Cîtaux (Côte-d'Or), France. Doc. Pedozool., **1** : 74-88.

FERRIERE, G., 1980. Fonctions des lombriciens. VII. Une méthode d'analyse de la matière organique végétale ingérée. Pedobiologia **20** : 263-273.

GHABBOUR, S. I.; W. Z. MIKHAIL AND RIZK, M.A., 1977. Ecology of soil fauna of Mediterranean desert ecosystems in Egypt. I. — Summer populations of soil mesofauna associated with major shrubs in the littoral sand dunes. Rev. Ecol. Biol. Sol, **14** : 429-459.

HANSSON, L., 1970. Methods of morphological diet micro-analysis in rodents. Oikos **21** : 255-266.

HEGAZI, E. M.; M. M. RAMADAN, E. A. SABRY AND M. A. SHAABAN, 1978. Invertebrates : epigeal fauna. SAMDENE Progress Report No. **4**, vol. 2, ch. 3 : 1-27.

INNIS, G. S., 1978. Grassland Simulation Model. Springer-Verlag, New York.

KASSAS, M. AND BISWAS, A. K., 1979. Agriculture, development and environment. Mazingira, **11** : 4-6.

TAECKHOLM, V.. 1974. Students' Flora of Egypt. 2nd ed., Cairo University.

WASSIF, K. AND S. SOLIMAN, 1979. The food of some wild rodents in the Western Desert of Egypt. Bull. Zool. Soc. Egypt, **29** : 43-51.

EXPLANATION OF FIGURES IN PLATES

PLATE I. A — **Thymelaea hirsuta,** leaf litter, outer margin showing hexagonal epidermal cells with thickened walls and no hairs.

B — **T. hirsuta,** leaf, litter, inner area of upper surface, showin sinewy hairs.

C — **Jasonia candicans,** leaf litter, showing "long" marginal hairs.

D — **J. candicans,** stem litter, showing "short" hairs.

E — **Lygos raetam,** stem litter, showing hairs on border of stem groove.

F — **Anabasis articulata,** stem litter, epidermis showing crystalline inclusions resembling mediaeval "mace-heads".

G — Natural faeces of **Porcellio laevis,** showing hexagonal cells, but unrelated to those of **T. hirsuta.**

H — Same material showing long sinewy hairs, unrelated to those of **T. hirsuta.**

Figures A to F, photographed by interferential contrast, Figs. G. and H by normal light. (× 60).

PLATE II. A — Fragments of plant cells in natural faeces of the desert isopod **Hemilepistus reaumuri,** from Bahig.

B — Stellate hairs from same material.

C — Pitted or reticulate xylem elements from same material, together with sand grains characteristic in the faeces of this isopod.

D — Disintegrated xylem thickening from same material.

E — Natural faeces of the sand roach, **Heterogamia syriaca,** from the littoral sand dunes at Gharbaniat, showing fragments of thick-walled hexagonal cells and sinewy hairs originating from **T. hirsuta** leaf litter.

F — Same material, showing plant fragments in a more disintegrated state than in Plate II E.

G — Same material, showing stellate hairs as in Plate II B.

H — Same material, showing individual sinewy hairs and fragments of xylem thickening.

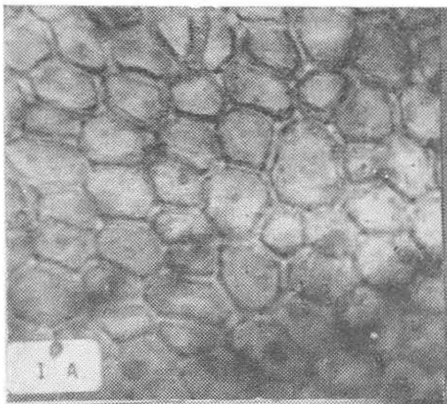
All figures photographed by interferential contrast (× 60).

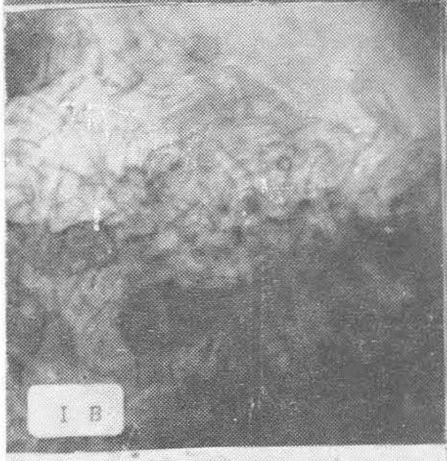
التعرف على الخلايا النباتية فى طعام ومخلفات أكلات النثار من لافقاريات التربة

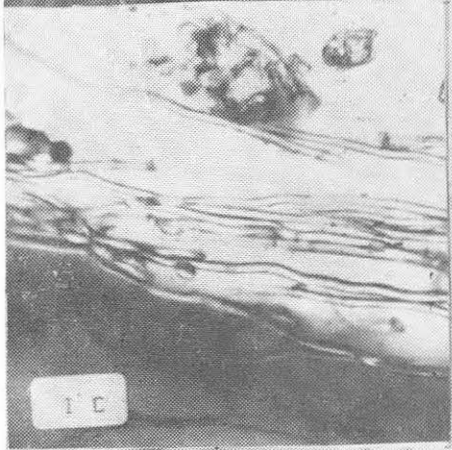
تأليف

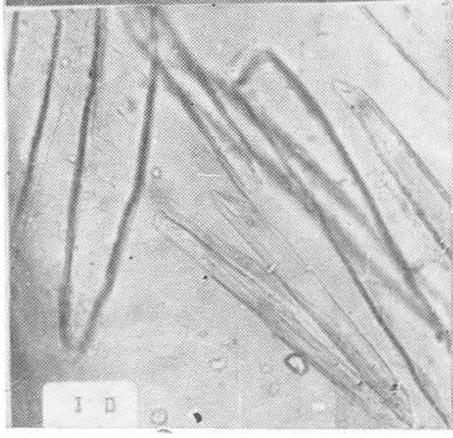
سمير ابراهيم غبور (١) ، جيرار فيريير (٢) ، مارجريت عدلى رزق (١)
(١) قسم الموارد الطبيعية ، معهد البحوث والدراسات الافريقية ، جامعة
القاهرة ، (٢) ومتحف التاريخ الطبيعى ديجون ، فرنسا

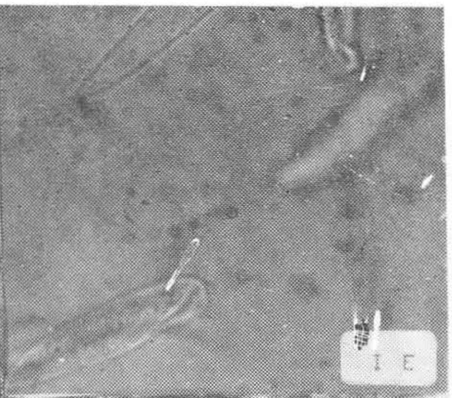
يصف هذا البحث طريقة لفحص الخلايا النباتية والتعرف عليهافى مخلفات أكلات النثار من لافقاريات التربة · وقد طبقت الطريقة على أكلات النثار من بيئات صحراوية من الساحل الشمالى الغربى لمصر هى نوع من متشابهة الأرجل ونوع من مستقيمة الاجنحة ونوعان من القواقع ، كما طبقت على نوع ثان من متشابهة الأرجل وجدت فى احدى حدائق القاهرة · وأوضح تطبيق هذه الطريقة أن كثافة الخلايا النباتية وتكرارها يمكن أن يستخدما لمقارنة مدى هضم النثار فى الأنواع المختلفة من لافقاريات التربة · ويمكن لهذه الطريقة أن تستخدم كأساس مفيد لايجاد علاقة كمية بين استهلاك الانواع المختلفة من الغذاء النباتى وخاصة النثار وبين هضمه فى اللافقاريات المختلفة ·

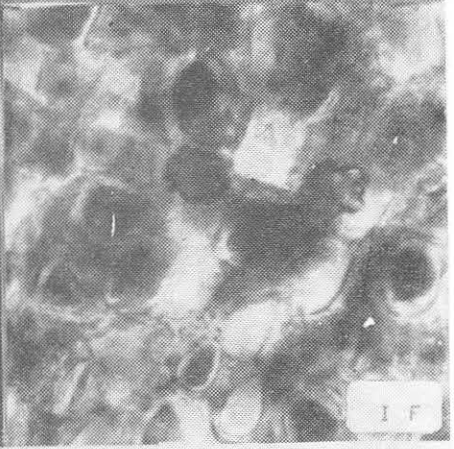

I A

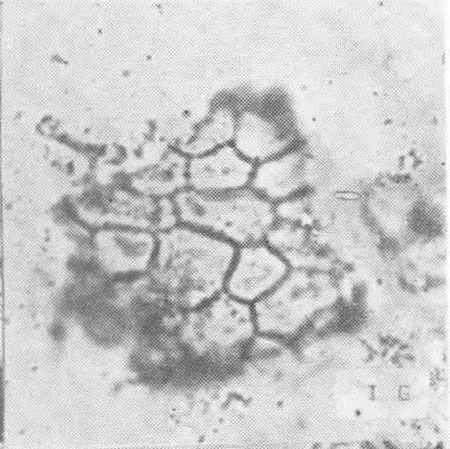

I B

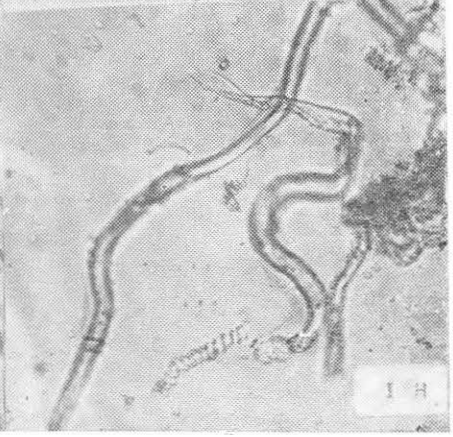

I C

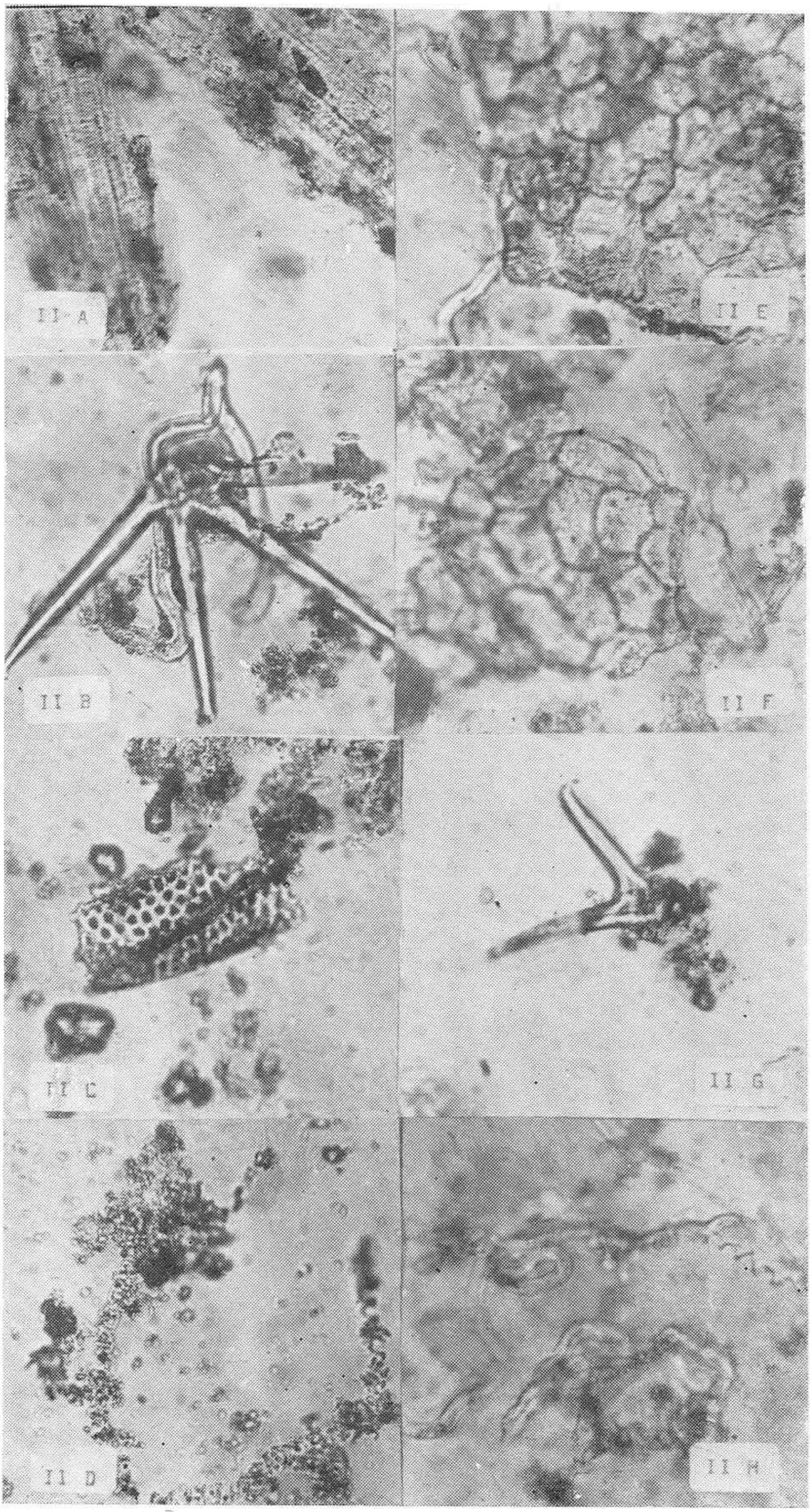

I D


I E


I F


I G


I H


II A
II E
II B
II F
II C
II G
II D
II H